

5. Electronic Structure of the Elements

Table 5.1: Reviewed 2022 by A. Kramida (NIST). The electronic configurations, ground state levels, and ionization energies are from A. Kramida, Yu. Ralchenko, J. Reader, and NIST ASD Team (2022), “NIST Atomic Spectra Database” (ver. 5.10), [Online], Available: <https://physics.nist.gov/asd> [2023, Sept 5]. National Institute of Standards and Technology, Gaithersburg, MD. DOI: <https://doi.org/10.18434/T4W30F>. The electron configuration for, say, iron indicates an argon electronic core (see argon) plus six 3*d* electrons and two 4*s* electrons.

	Element	Electron configuration (3 <i>d</i> ⁵ = five 3 <i>d</i> electrons, <i>etc.</i>)		Ground state ^{2<i>S</i>+1<i>L</i><i>J</i>}	Ionization energy (eV)
1	H	Hydrogen	1 <i>s</i>	² <i>S</i> _{1/2}	13.5984
2	He	Helium	1 <i>s</i> ²	¹ <i>S</i> ₀	24.5874
3	Li	Lithium	(He) 2 <i>s</i>	² <i>S</i> _{1/2}	5.3917
4	Be	Beryllium	(He) 2 <i>s</i> ²	¹ <i>S</i> ₀	9.3227
5	B	Boron	(He) 2 <i>s</i> ² 2 <i>p</i>	² <i>P</i> _{1/2} ^o	8.2980
6	C	Carbon	(He) 2 <i>s</i> ² 2 <i>p</i> ²	³ <i>P</i> ₀	11.2603
7	N	Nitrogen	(He) 2 <i>s</i> ² 2 <i>p</i> ³	⁴ <i>S</i> _{3/2} ^o	14.5341
8	O	Oxygen	(He) 2 <i>s</i> ² 2 <i>p</i> ⁴	³ <i>P</i> ₂	13.6181
9	F	Fluorine	(He) 2 <i>s</i> ² 2 <i>p</i> ⁵	² <i>P</i> _{3/2} ^o	17.4228
10	Ne	Neon	(He) 2 <i>s</i> ² 2 <i>p</i> ⁶	¹ <i>S</i> ₀	21.5645
11	Na	Sodium	(Ne) 3 <i>s</i>	² <i>S</i> _{1/2}	5.1391
12	Mg	Magnesium	(Ne) 3 <i>s</i> ²	¹ <i>S</i> ₀	7.6462
13	Al	Aluminum	(Ne) 3 <i>s</i> ² 3 <i>p</i>	² <i>P</i> _{1/2} ^o	5.9858
14	Si	Silicon	(Ne) 3 <i>s</i> ² 3 <i>p</i> ²	³ <i>P</i> ₀	8.1517
15	P	Phosphorus	(Ne) 3 <i>s</i> ² 3 <i>p</i> ³	⁴ <i>S</i> _{3/2} ^o	10.4867
16	S	Sulfur	(Ne) 3 <i>s</i> ² 3 <i>p</i> ⁴	³ <i>P</i> ₂	10.3600
17	Cl	Chlorine	(Ne) 3 <i>s</i> ² 3 <i>p</i> ⁵	² <i>P</i> _{3/2} ^o	12.9676
18	Ar	Argon	(Ne) 3 <i>s</i> ² 3 <i>p</i> ⁶	¹ <i>S</i> ₀	15.7596
19	K	Potassium	(Ar) 4 <i>s</i>	² <i>S</i> _{1/2}	4.3407
20	Ca	Calcium	(Ar) 4 <i>s</i> ²	¹ <i>S</i> ₀	6.1132
21	Sc	Scandium	(Ar) 3 <i>d</i> 4 <i>s</i> ²	T ² <i>D</i> _{3/2}	6.5615
22	Ti	Titanium	(Ar) 3 <i>d</i> ² 4 <i>s</i> ²	r e ³ <i>F</i> ₂	6.8281
23	V	Vanadium	(Ar) 3 <i>d</i> ³ 4 <i>s</i> ²	a l ⁴ <i>F</i> _{3/2}	6.7462
24	Cr	Chromium	(Ar) 3 <i>d</i> ⁵ 4 <i>s</i>	n e ⁷ <i>S</i> ₃	6.7665
25	Mn	Manganese	(Ar) 3 <i>d</i> ⁵ 4 <i>s</i> ²	s m ⁶ <i>S</i> _{5/2}	7.4340
26	Fe	Iron	(Ar) 3 <i>d</i> ⁶ 4 <i>s</i> ²	i e ⁵ <i>D</i> ₄	7.9025
27	Co	Cobalt	(Ar) 3 <i>d</i> ⁷ 4 <i>s</i> ²	t n ⁴ <i>F</i> _{9/2}	7.8810
28	Ni	Nickel	(Ar) 3 <i>d</i> ⁸ 4 <i>s</i> ²	i t ³ <i>F</i> ₄	7.6399
29	Cu	Copper	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i>	o s ² <i>S</i> _{1/2}	7.7264
30	Zn	Zinc	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i> ²	n ¹ <i>S</i> ₀	9.3942
31	Ga	Gallium	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i> ² 4 <i>p</i>	² <i>P</i> _{1/2} ^o	5.9993
32	Ge	Germanium	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i> ² 4 <i>p</i> ²	³ <i>P</i> ₀	7.8994
33	As	Arsenic	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i> ² 4 <i>p</i> ³	⁴ <i>S</i> _{3/2} ^o	9.7886
34	Se	Selenium	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i> ² 4 <i>p</i> ⁴	³ <i>P</i> ₂	9.7524
35	Br	Bromine	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i> ² 4 <i>p</i> ⁵	² <i>P</i> _{3/2} ^o	11.8138
36	Kr	Krypton	(Ar) 3 <i>d</i> ¹⁰ 4 <i>s</i> ² 4 <i>p</i> ⁶	¹ <i>S</i> ₀	13.9996
37	Rb	Rubidium	(Kr) 5 <i>s</i>	² <i>S</i> _{1/2}	4.1771
38	Sr	Strontium	(Kr) 5 <i>s</i> ²	¹ <i>S</i> ₀	5.6949
39	Y	Yttrium	(Kr) 4 <i>d</i> 5 <i>s</i> ²	T ² <i>D</i> _{3/2}	6.2173
40	Zr	Zirconium	(Kr) 4 <i>d</i> ² 5 <i>s</i> ²	r e ³ <i>F</i> ₂	6.6341
41	Nb	Niobium	(Kr) 4 <i>d</i> ⁴ 5 <i>s</i>	a l ⁶ <i>D</i> _{1/2}	6.7589
42	Mo	Molybdenum	(Kr) 4 <i>d</i> ⁵ 5 <i>s</i>	n e ⁷ <i>S</i> ₃	7.0924
43	Tc	Technetium	(Kr) 4 <i>d</i> ⁵ 5 <i>s</i> ²	s m ⁶ <i>S</i> _{5/2}	7.1194
44	Ru	Ruthenium	(Kr) 4 <i>d</i> ⁷ 5 <i>s</i>	i e ⁵ <i>F</i> ₅	7.3605
45	Rh	Rhodium	(Kr) 4 <i>d</i> ⁸ 5 <i>s</i>	t n ⁴ <i>F</i> _{9/2}	7.4589
46	Pd	Palladium	(Kr) 4 <i>d</i> ¹⁰	i t ¹ <i>S</i> ₀	8.3368
47	Ag	Silver	(Kr) 4 <i>d</i> ¹⁰ 5 <i>s</i>	o s ² <i>S</i> _{1/2}	7.5762
48	Cd	Cadmium	(Kr) 4 <i>d</i> ¹⁰ 5 <i>s</i> ²	n ¹ <i>S</i> ₀	8.9938

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Element	Electron configuration ($3d^5 =$ five $3d$ electrons, <i>etc.</i>)	Ground state $2S+1L_J$	Ionization energy (eV)
49 In	Indium (Kr) $4d^{10} 5s^2 5p$	$2P_{1/2}^o$	5.7864
50 Sn	Tin (Kr) $4d^{10} 5s^2 5p^2$	$3P_0^o$	7.3439
51 Sb	Antimony (Kr) $4d^{10} 5s^2 5p^3$	$4S_{3/2}^o$	8.6084
52 Te	Tellurium (Kr) $4d^{10} 5s^2 5p^4$	$3P_2^o$	9.0098
53 I	Iodine (Kr) $4d^{10} 5s^2 5p^5$	$2F_{3/2}^o$	10.4513
54 Xe	Xenon (Kr) $4d^{10} 5s^2 5p^6$	$1S_0$	12.1298
55 Cs	Cesium (Xe) $6s$	$2S_{1/2}$	3.8939
56 Ba	Barium (Xe) $6s^2$	$1S_0$	5.2117
57 La	Lanthanum (Xe) $5d 6s^2$	$2D_{3/2}$	5.5769
58 Ce	Cerium (Xe) $4f 5d 6s^2$	$1G_4^o$	5.5386
59 Pr	Praseodymium (Xe) $4f^3 6s^2$	L $4I_{9/2}^o$	5.4702
60 Nd	Neodymium (Xe) $4f^4 6s^2$	a $5I_4$	5.5250
61 Pm	Promethium (Xe) $4f^5 6s^2$	n $6H_{5/2}^o$	5.5819
62 Sm	Samarium (Xe) $4f^6 6s^2$	t $7F_0$	5.6437
63 Eu	Europium (Xe) $4f^7 6s^2$	a $8S_{7/2}^o$	5.6704
64 Gd	Gadolinium (Xe) $4f^7 5d 6s^2$	n $9D_2^o$	6.1498
65 Tb	Terbium (Xe) $4f^9 6s^2$	i $6H_{5/2}^o$	5.8638
66 Dy	Dysprosium (Xe) $4f^{10} 6s^2$	d $5I_8$	5.9391
67 Ho	Holmium (Xe) $4f^{11} 6s^2$	e $4I_{15/2}^o$	6.0215
68 Er	Erbium (Xe) $4f^{12} 6s^2$	s $3H_6$	6.1077
69 Tm	Thulium (Xe) $4f^{13} 6s^2$	$2F_{7/2}^o$	6.1844
70 Yb	Ytterbium (Xe) $4f^{14} 6s^2$	$1S_0$	6.2542
71 Lu	Lutetium (Xe) $4f^{14} 5d 6s^2$	$2D_{3/2}$	5.4259
72 Hf	Hafnium (Xe) $4f^{14} 5d^2 6s^2$	T $3F_2$	6.8251
73 Ta	Tantalum (Xe) $4f^{14} 5d^3 6s^2$	r e $4F_{3/2}$	7.5496
74 W	Tungsten (Xe) $4f^{14} 5d^4 6s^2$	a l $5D_0$	7.8640
75 Re	Rhenium (Xe) $4f^{14} 5d^5 6s^2$	n e $6S_{5/2}^o$	7.8335
76 Os	Osmium (Xe) $4f^{14} 5d^6 6s^2$	s m $5D_4$	8.4382
77 Ir	Iridium (Xe) $4f^{14} 5d^7 6s^2$	i e $4F_{9/2}$	8.9670
78 Pt	Platinum (Xe) $4f^{14} 5d^9 6s$	t n $3D_3$	8.9588
79 Au	Gold (Xe) $4f^{14} 5d^{10} 6s$	i t $2S_{1/2}$	9.2256
80 Hg	Mercury (Xe) $4f^{14} 5d^{10} 6s^2$	o s $1S_0$	10.4375
81 Tl	Thallium (Hg) $6p$	$2P_{1/2}^o$	6.1083
82 Pb	Lead (Hg) $6p^2$	$3P_0^o$	7.4167
83 Bi	Bismuth (Hg) $6p^3$	$4S_{3/2}^o$	7.2855
84 Po	Polonium (Hg) $6p^4$	$3P_2^o$	8.4181
85 At	Astatine (Hg) $6p^5$	$2P_{3/2}^o$	9.3175
86 Rn	Radon (Hg) $6p^6$	$1S_0$	10.7485
87 Fr	Francium (Rn) $7s$	$2S_{1/2}$	4.0727
88 Ra	Radium (Rn) $7s^2$	$1S_0$	5.2784
89 Ac	Actinium (Rn) $6d 7s^2$	$2D_{3/2}$	5.3802
90 Th	Thorium (Rn) $6d^2 7s^2$	$3F_2$	6.3067
91 Pa	Protactinium (Rn) $5f^2 6d 7s^2$	A $4K_{11/2}^*$	5.89
92 U	Uranium (Rn) $5f^3 6d 7s^2$	c $5I_6^o$	6.1941
93 Np	Neptunium (Rn) $5f^4 6d 7s^2$	t $6L_{11/2}^*$	6.2655
94 Pu	Plutonium (Rn) $5f^6 7s^2$	i $7F_0$	6.0258
95 Am	Americium (Rn) $5f^7 7s^2$	n $8S_{7/2}^o$	5.9738
96 Cm	Curium (Rn) $5f^7 6d 7s^2$	i $9D_2^o$	5.9914
97 Bk	Berkelium (Rn) $5f^9 7s^2$	d $6H_{15/2}^o$	6.1979
98 Cf	Californium (Rn) $5f^{10} 7s^2$	e $5I_8$	6.2819
99 Es	Einsteinium (Rn) $5f^{11} 7s^2$	s $4I_{15/2}^o$	6.3676
100 Fm	Fermium (Rn) $5f^{12} 7s^2$	$3H_6$	6.50
101 Md	Mendelevium (Rn) $5f^{13} 7s^2$	$2F_{7/2}^o$	6.58
102 No	Nobelium (Rn) $5f^{14} 7s^2$	$1S_0$	6.6262
103 Lr	Lawrencium (Rn) $5f^{14} 7s^2 7p$	$2P_{1/2}^o$	4.96
104 Rf	Rutherfordium (Rn) $5f^{14} 6d^2 7s^2$	$3F_2$	6.02
105 Db	Dubnium (Rn) $5f^{14} 6d^3 7s^2$	$4F_{3/2}$	6.8
106 Sg	Seaborgium (Rn) $5f^{14} 6d^4 7s^2$	0	7.8
107 Bh	Bohrium (Rn) $5f^{14} 6d^5 7s^2$	$5/2$	7.7
108 Hs	Hassium (Rn) $5f^{14} 6d^6 7s^2$	4	7.6

* The usual LS coupling scheme does not apply for these three elements.

See the introductory note to the NIST table at https://www.nist.gov/pml/data/ion_energy.cfm.